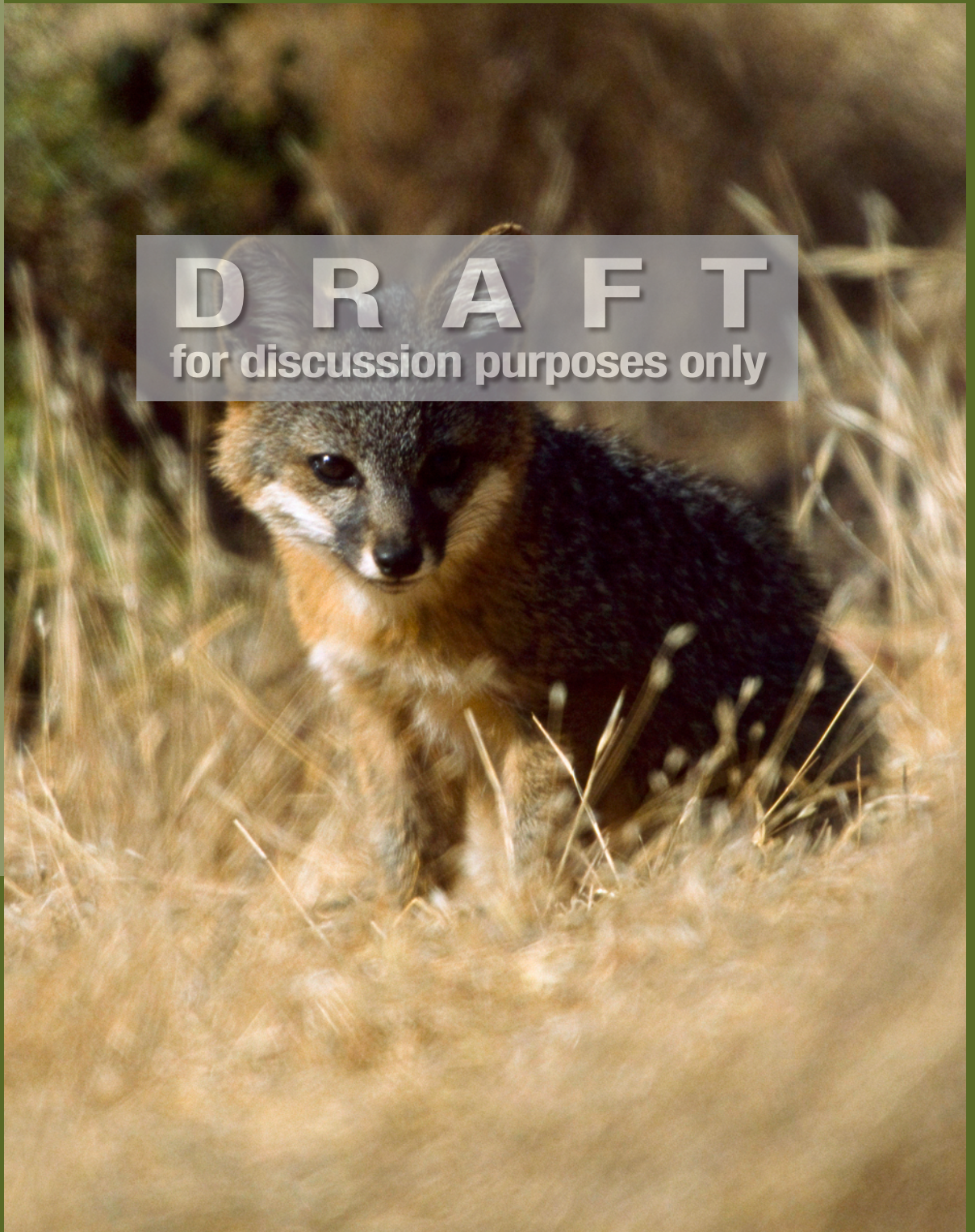


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Biology
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The Isolation of Species

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California Education and the Environment Initiative

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Name: _____

Multiple Choice: Select the best answer and circle the correct letter. (1 point each)

1. Isolated islands often have many endemic species that evolved from species on the closest continent. These endemic species form through which process:
 - a. geographic isolation
 - b. resource isolation
 - c. migratory routes
 - d. specialized adaptations to global warming
2. Which of the following processes support the occurrence of allopatric speciation?
 - a. erosion of mountains
 - b. isolation on islands
 - c. migration between regions
 - d. interbreeding between populations
3. How do reproductive isolating mechanisms (RIMs) contribute to speciation?
 - a. They prevent interbreeding between two species or populations.
 - b. They prevent breeding between less fit individuals.
 - c. They result in offspring with higher fitness levels.
 - d. They allow two populations to interbreed.
 - e. They allow populations to converge into one species.
4. Examples of reproductive isolating mechanisms (RIMs) that occur between species include all of the following except:
 - a. They look different from each other.
 - b. They have a different odor.
 - c. They behave differently.
 - d. They are geographically isolated from each.
5. What is the primary reason that habitat fragmentation poses problems for species?
 - a. It allows for the introduction of non-native species.
 - b. It opens migration routes.
 - c. It isolates a large population into smaller groups.
 - d. It limits the food resources of animals.
6. All of the following human activities increase the isolation of species except:
 - a. Habitat fragmentation.
 - b. Introduction of non-native species.
 - c. Hunting a population to low numbers.
 - d. Breeding programs.

Isolation and Species

Name: _____

7. Many species in the Galápagos are sensitive to environmental changes induced by the events of El Niño because of their inability to:
- a. Migrate to new regions to find new food resources.
 - b. Survive temperature changes.
 - c. Adapt to new predators.
 - d. Find suitable breeding sites.

8. Provide three examples of how geographic isolation of a species may occur: (3 points)

9. For each of the following, circle whether it caused an increase or a decrease in the isolation of species and explain how it caused this change. (1 point for increase or decrease, 2 points for explanation)

- a. Captive breeding programs (increase or decrease)

- b. Habitat fragmentation (increase or decrease)

- c. Introduction of non-native species (increase or decrease)

- d. Hunting (increase or decrease)

Isolation and Species

Name: _____

- e. Protection in a reserve (increase or decrease):

10. Describe three ways non-native species influence the geographic or reproductive isolation of native species. (2 points each)

11. Explain why species on island systems are more sensitive to rapid environmental change (either natural or human induced). (5 points total)

The Isolation of Native Species

Alternative Unit Assessment Master | page 1 of 2

Name: _____

Read Island Case Study and answer the following questions.

1. Describe how the Hawaiian Islands' geographic isolation influences the speciation of the native island goose, the nene. (2 points: one point for describing the isolation, one point for including genetic divergence)

2. Describe three human activities that contribute to the geographic isolation of the nene. First list the activity, then explain how it contributes to isolation. (4 points each)

3. Explain four factors related to island environments that make native island species vulnerable to rapid environmental changes.(1 point each)

The Isolation of Native Species

Alternative Unit Assessment Master | page 2 of 2

4. Identify and describe four ways that non-native species can influence the populations of native species (the Hawaiian nene). (2 points each)

5. Describe two ways that the introduction of non-native species influences the isolation of native species and how this isolation may influence the speciation of the native species' populations. (2 points each)

Island Case Study

Located more than a thousand miles from the nearest continent, the Hawaiian Islands comprise one of the most isolated island chains in the world. They are considered a biodiversity hotspot, a biogeographic region with a significant reservoir of biodiversity that is threatened with destruction. Of the 20,000 native species identified on the islands, more than half are endemic, yet the islands have only two endemic mammals: the Hawaiian hoary bat and Hawaiian monk seal. There are no endemic snakes, but there are over 60 endemic bird species.

Recent impacts to the islands' habitats have led to an extinction of 8% of the native species, and the listing of 29% of native species as either endangered or threatened. The use of land for plantations of sugar cane, pineapple, and coffee has fragmented, altered, or destroyed native habitat. Further, it has resulted in the introduction of non-native species that prey on native wildlife. In addition, the human population has increased exponentially on the islands, with a 16% increase over the 10 years between 1990 and 2000. The swelling population



Mongoose



Hawaiian geese

has resulted in the development of housing tracts, resorts, and condominiums, in many of the islands' coastal areas.

The Hawaii nene, or nēnē, (pronounced “naynay”) is one of the most threatened endemic birds on the islands. Genetic studies indicate that it is a close relative of the Canada goose. It is estimated that in the late 1700s, the population was around 25,000. By 1952 only 30 remained alive. Captive breeding

programs have allowed the population to recover to 800—all bred from those remaining 30 individuals. Nene are found in scattered pockets throughout the islands, often in protected areas.

The nene is a ground-nesting bird that prefers to nest in the lowlands amongst short vegetation. It has a long nesting season, and goslings take three months to fledge (be able to fly.) The nenes ancestors had few natural predators when they

Island Case study



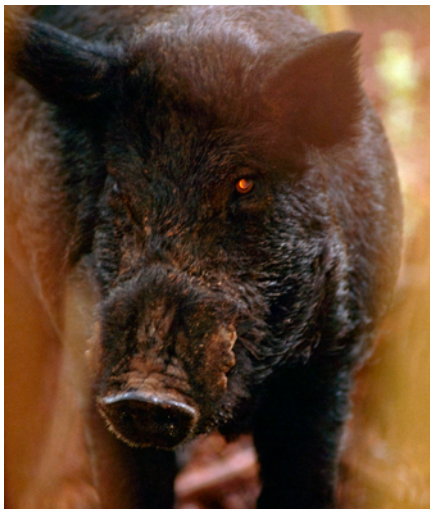
Hawaiian Islands

arrived on the Hawaiian Islands. As a result, the nene lost some of its ancestors' adaptations for avoiding predators. And, ground

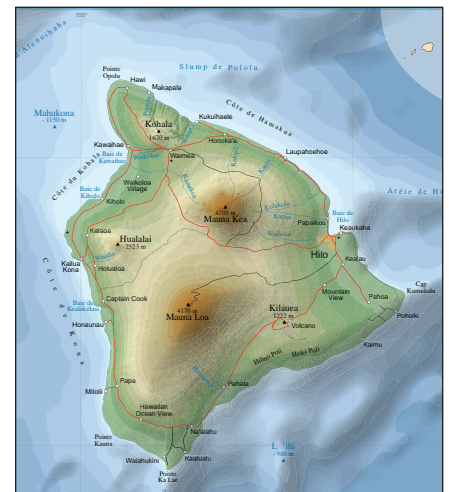
predation is what the non-native mongoose does.

In 1833, the mongoose was introduced to the islands in the hopes of combating the rat population in the sugarcane fields. The quickly-reproducing mongoose ate more than rats, however. It preys on many small animals, insects, eggs, and juvenile birds. Another non-native, the pig, has a much longer history on the islands, dating back to 400 A.D. It was brought to the islands by sailors as a food resource in case they were stranded there. This non-native travels in packs. Its rooting behavior (in search of food) and

wallowing behavior (to cool down) disrupts vegetation. The feral pig is also known to feed on the eggs of ground-nesting birds like the nene.



Feral pig



"Big Island" of Hawaii

Key Unit Vocabulary

Lesson 1 Activity Master

Allopatric speciation: The formation of new species due to geographical separation.

Chlorophyll concentration: The quantity of phytoplankton in a volume of water.

Dispersal: The movement of an organism from established habitats to a new location.

Divergence: In terms of genetics, the genetic differences, that occur over time, between closely related organisms.

El Niño: A 2–10 year climate cycle that alters rainfall patterns and sea surface temperatures across the Pacific Ocean.

Endemic: (noun) Species or taxa found only in a specified geographic region. (adjective) Prevalent in a particular region.

Gene flow: The movement of genetic material between two populations by successful interbreeding.

Generalist feeder: A consumer that eats a wide variety of foods, including plants, animals, and detritus.

Genetic drift: Changes in allele frequencies in populations that result from the random sampling of alleles from generation to generation and the chance survival and reproduction of individuals.

Geographic isolation: The separation of populations due to a geographic feature (natural or human-made).

Grazers: Herbivores that feed on plants such as grass or other low vegetation.

Habitat fragmentation: The division of an ecosystem into more isolated areas as a result of natural or human activities.

Hybrid: Offspring of two animals or plants of different varieties, species or genera.

Out-compete: More effectively finding and using resource, such as food or nesting sites, than another species.

Phytoplankton: Photosynthetic plankton, such as diatoms and dinoflagellates, that are capable of producing food energy.

Population: The number of individuals belonging to a species or several species living in a place at a given time.

Reproductive isolation mechanism (RIM): Morphological or physiological characteristic that inhibits interbreeding between two or more populations.

Speciation: The process through which new species are formed.

Species: A classification of organisms that closely resemble one another, and breed to produce offspring that are viable and themselves can successfully reproduce.

Subspecies: A group of organisms within a species that has distinct characteristics resulting from their geographical or physical isolation from other populations of their species.

Viable: Usually refers to offspring in the egg stage in terms of their ability to survive.

Wildlife trafficking: Illegal capture, transport, and sale of animals, often involving endangered species.

Zooplankton: Animals, such as copepods, jellies (jellyfish), and fish larvae that are part of the plankton that drift with currents.

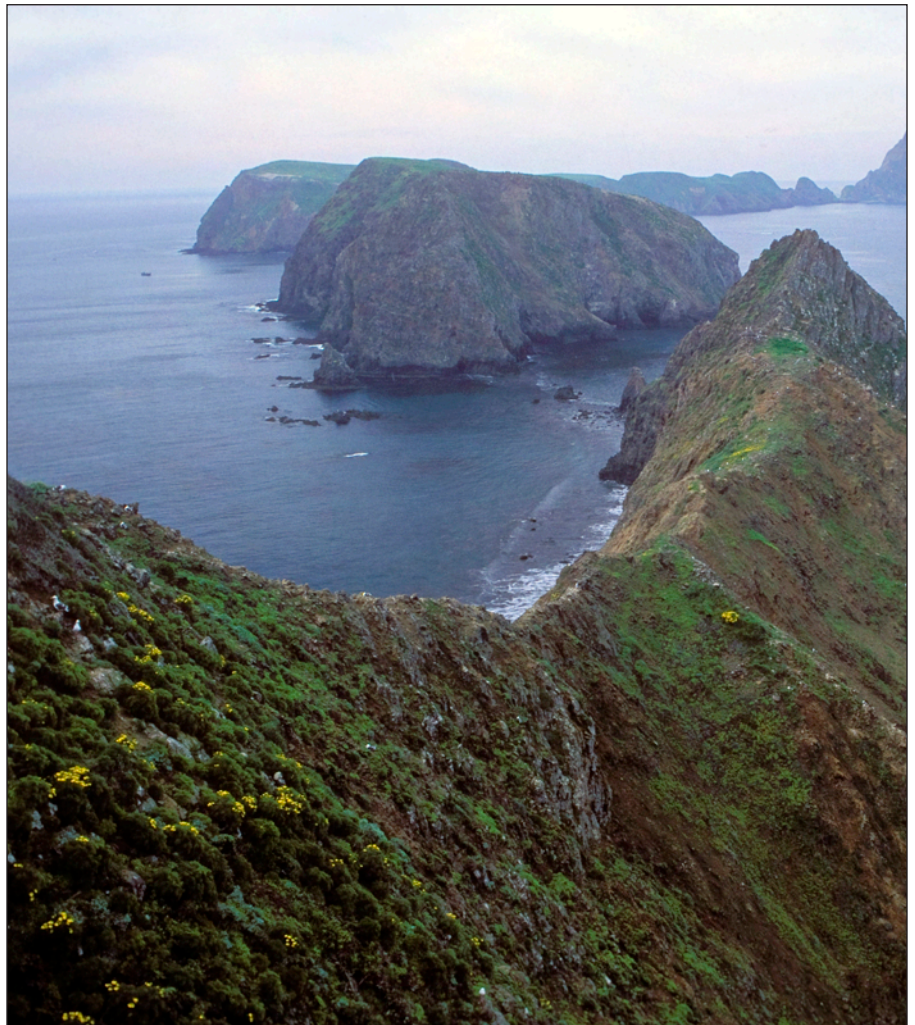
The Channel Islands— The Galápagos of California

You do not have to travel to the Southern Hemisphere to see pristine islands with unique plants and animals. With a short boat ride, you can leave the developed coastline of Southern California and visit the untamed coasts of the Channel Islands. This chain of islands lies within 60 miles of mainland California. It extends from Point Conception at the western end of the Santa Barbara Channel to the U.S.-Mexico border.



The Channel Islands of Southern California are often compared to the Galápagos Islands of South America. The eight islands

harbor over 100 endemic species, which means they are found nowhere else on Earth. For example, the island night lizard is a species unique to three of the Channel Islands (Santa Barbara Island, San Clemente Island, and San Nicolas Island). This lizard has an extremely small home range. Once it finds a territory, it usually doesn't wander more than 10 feet in any direction. Santa Cruz Island is the sole home of the island scrub jay, a species that is larger and brighter than the mainland western scrub jay. Two species from California's mainland that have formed unique species and subspecies



California Channel Islands

on the Channel Islands are the island deer mouse and the island fox. The island deer mouse is the only native mammal found on all eight of the Channel Islands. Each of these island populations is considered a different subspecies of island deer mouse. The endemic island fox has also diverged into separate subspecies on each of the six islands on which it lives. There are many endemic plants on the islands as well. They include island ironwoods and island oaks, the giant buckwheat, and varieties of manzanita, milk-vetch, bedstraw, lotus, and phacelia. Because these species and subspecies are endemic and found in such small areas, they are part of one of the most rare and endangered ecosystems in the world.

How do such unique organisms develop? The answer is through allopatric speciation, a process that occurs when one population of a single species is split into two populations that are isolated from each other for a long period of time. Speciation is due to the two populations living in different environments that have different species of plants and animals. When one population lives in a particular environment, some individuals of that population may have traits that make it more likely that those individuals will survive and reproduce. These traits will be



Channel Island Deer mouse

different for the two populations living in different environments. Because these populations are isolated the traits will not be shared between populations. Over time each population will develop its own set of traits that are different from the traits in the other population. After a long time the populations will be so different that they can be considered separate species.

The fox populations of the northern Channel Islands provide a clear example of allopatric speciation. The four northern islands—San Miguel, Santa Rosa, Santa Cruz, and Anacapa—were contiguous approximately 18,000 years ago during the Pleistocene Ice Age, when sea levels were lower. Joined together, they formed one large island

known now as Santa Rosae. This island was home to the endemic island fox, a species that had evolved from the mainland gray fox. When sea levels rose, only the higher elevations of Santa Rosae remained above water. This divided the island into four separate islands. The four new islands held four isolated fox populations. Each population diverged on its own path of evolution. After a long period of separation, these populations each developed unique traits. For example, each island's fox has a different number of tail vertebrae. There is other evidence of divergence in the island fox populations. With time, these isolated subspecies of island fox could evolve into separate species.

To some extent, the farther an island is from the mainland, the more endemic species it will have. This is true for many island chains worldwide, including the Galápagos. We can also see this trend in the Channel Islands. Anacapa, the closest island, is 12 miles away from the mainland. The southern Channel Islands—Santa Catalina, Santa Barbara, San Nicolas, and San Clemente—were never connected to one another and are generally farther away from the mainland than the northern islands. The northern islands have up to 13 endemic plant

species on a single island. The more isolated southern islands have as many as 30 single-island endemic plant species.

Isolation and evolution have caused dramatic differences between similar species living on mainland California versus on the Channel Islands. Some island species are larger than their mainland relatives. Such “gigantism” is seen in island scrub jays, island deer mice, and giant buckwheat. Another evolutionary change is dwarfism, where, over time, island organisms evolve to smaller sizes than their mainland

relatives. This can be seen in the island fox, which is the size of a housecat—half the size of the mainland gray fox.

One striking example of evolutionary dwarfism is the Channel Island's pygmy mammoth. Evidence shows that when mammoths first colonized Santa Rosae by swimming six miles to the island during the last ice age, they were the same size as mainland mammoths—14 feet tall and weighing about 22,000 pounds. Within 20,000 years, a new species—pygmy mammoth—had emerged on the islands, standing only 5-6 feet tall and weighing 2,000 pounds. Scientists believe that the increased competition, brought about by living in the “close quarters” of the islands, was the cause of this dwarfism. As sea levels rose, less food was available. Smaller animals need less food to survive. Also, there were no predators on the islands, so large size was not a beneficial defensive trait. Over time and many generations, natural selection whittled this species to a smaller size to better fit the new island environment. (Both the Channel Island's pygmy mammoth and its mainland relatives are now extinct.)

Yet the traits that make island species successful in the island environment can also make them vulnerable to extinction. Because their gene



Channel Island scrub jay

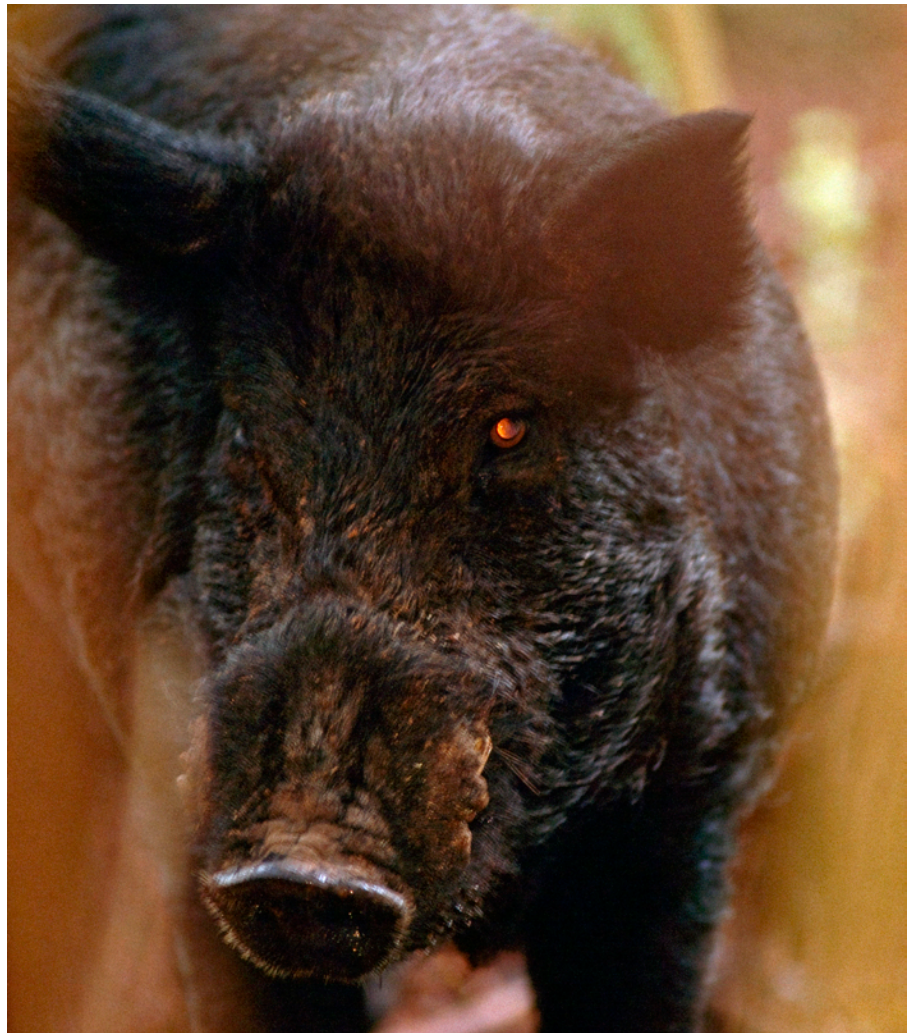
pool is small, island species do not have much resilience to environmental changes. If a disaster occurs—such as a tsunami or the introduction of a new disease—the entire population can become extinct in a short period of time. This almost happened to island foxes living on Santa Catalina Island. When canine distemper virus was introduced to the population by a domestic dog in the early 1990s, 90% of this endemic subspecies vanished within a year. The isolation of the islands also makes possible the danger of inbreeding which can result in decreased fertility, increased genetic disorders, and higher mortality rates within a species.

Non-native species influence the survival of endemic populations on the Channel Islands as well. In fact, one-fourth of all plant species on the islands today are “introduced” species. Many of these newly introduced species out-compete native plants for space and water, or simply eat them out of existence. They are no match for the herbivores, such as goats, rabbits, deer, and pigs, that have been introduced to the islands. The islands’ wildlife often evolve without predators. If a predator is introduced to the island, native species cannot defend themselves. Feral cats and black rats eat seabird and songbird

eggs and chicks. Feral pigs on the islands destroy native vegetation, causing erosion. The year-round availability of piglets once supported the non-native golden eagle population, which further endangered the island fox populations since island fox kits (young) are also prey to the eagles.

All life forms are the result of millions of years of mutation, random chance, and natural selection. Once a species is

gone, it is gone forever. The Channel Islands are among the world’s most precious resources. They provide nurseries essential breeding grounds for over 90% of sea birds in southern California. They also offer sanctuary for a rich diversity of marine life. Many threatened and endangered species exist in the Channel Islands and their surrounding waters. These islands are “living laboratories” of evolution.



Feral pig

Geographic Isolation of Species

Lesson 1 Activity Master | page 1 of 2

Name: _____

1. Describe five possible ways in which organisms could have arrived on the Channel Islands. (3 points)

2. Complete the following chart. Describe the possibility of each type of organism dispersing to the islands around the last ice age; provide an explanation for your probability selection, and describe the mechanism by which each type could arrive on the islands. (1 point for each cell)

Dispersing to the Islands

Organism	Probability of arriving on the Islands High or Low	Rationale	Mechanism of Arrival
Large land mammal			
Small land mammal			
Marine mammal			
Bird			
Reptile			
Amphibian			

Geographic Isolation of Species

Lesson 1 Activity Master | page 2 of 2

3. Use the Channel Islands or Grand Canyon examples to answer the following questions.
(5 points each)

a. What is geographic isolation?

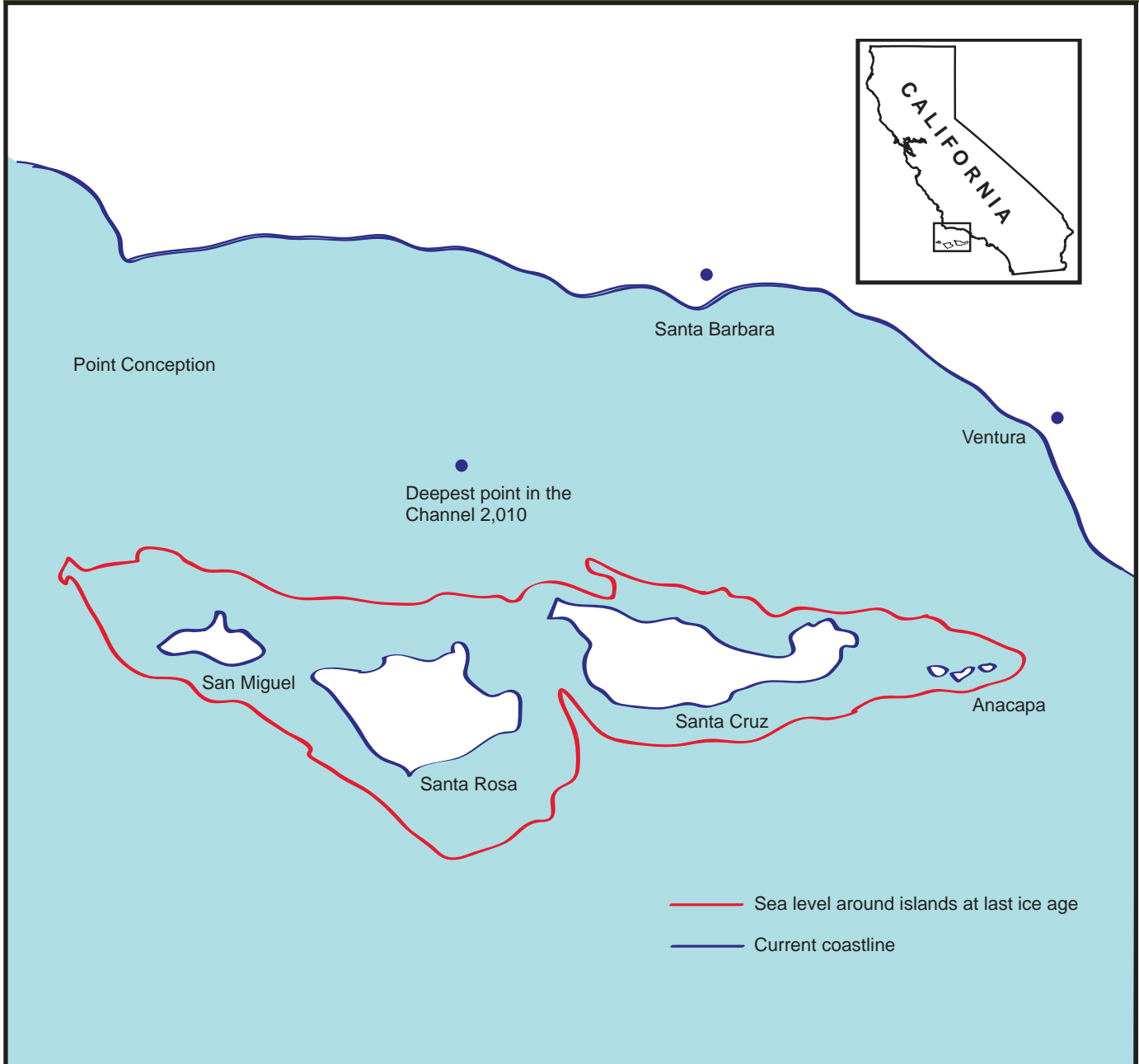
b. What is speciation?

c. How does geographic isolation affect speciation? Provide an example.

California's Channel Islands



Depiction of Prehistoric Channel Islands



Getting to the Islands



Kaibab Squirrel



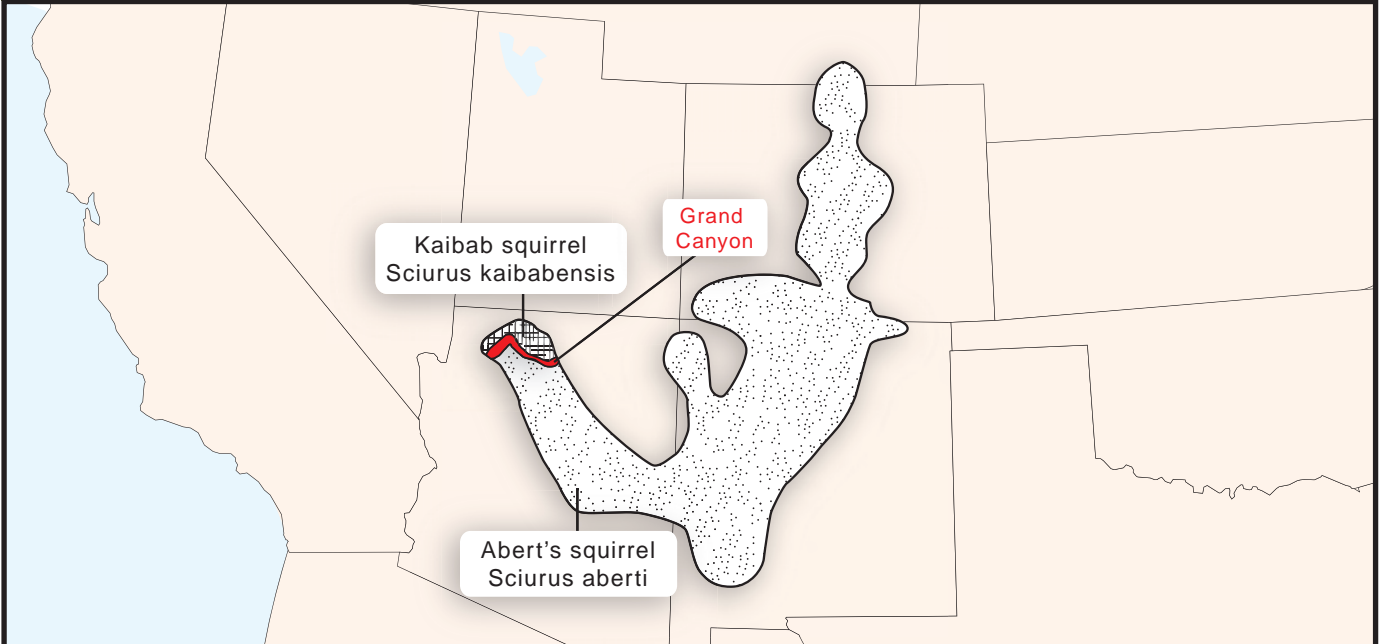
Abert's Squirrel



Dispersing to the Islands

Organism	Probability of arriving on the Islands High or Low	Rationale	Mechanism of Arrival
Large land mammal			
Small land mammal			
Marine mammal			
Bird			
Reptile			
Amphibian			

Distribution of Abert's and Kaibab Squirrel



Mechanisms of Species Isolation

Lesson 2 Activity Master | page 1 of 2

Name: _____

1. Examine the transparencies of the following organisms. Describe the morphological differences between the island species and its mainland source species. Include size, color, shape, and any other relevant features. (4 points each)

- a. Island fox versus gray fox

- b. Santa Cruz scrub jay versus western (mainland) scrub jay

- c. Island redberry versus redberry (mainland)

2. Examine the map of the Galápagos Islands. (4 points each)

- a. Explain how the giant tortoise subspecies may have evolved.

- b. On Isabela Island, there are five subspecies of giant tortoise, one located on each of the island's five volcanoes. Propose an explanation for why these tortoises remain isolated from each other.

Mechanisms of Species Isolation

Lesson 2 Activity Master | page 2 of 2

Name: _____

3. Review the map of the Channel Islands. There are six subspecies of island fox one on each of six of the eight islands. Explain how these six subspecies may have evolved from a single source species. (4 points)

4. List three examples of reproductive isolating mechanisms. (6 points)

5. How does geographic isolation contribute to speciation? (Include a discussion of reproductive isolating mechanisms in your explanation.) (4 points)

Island Fox versus Gray Fox



Santa Cruz Scrub Jay versus Western Scrub Jay



Island Scrub Jay



Western Scrub Jay

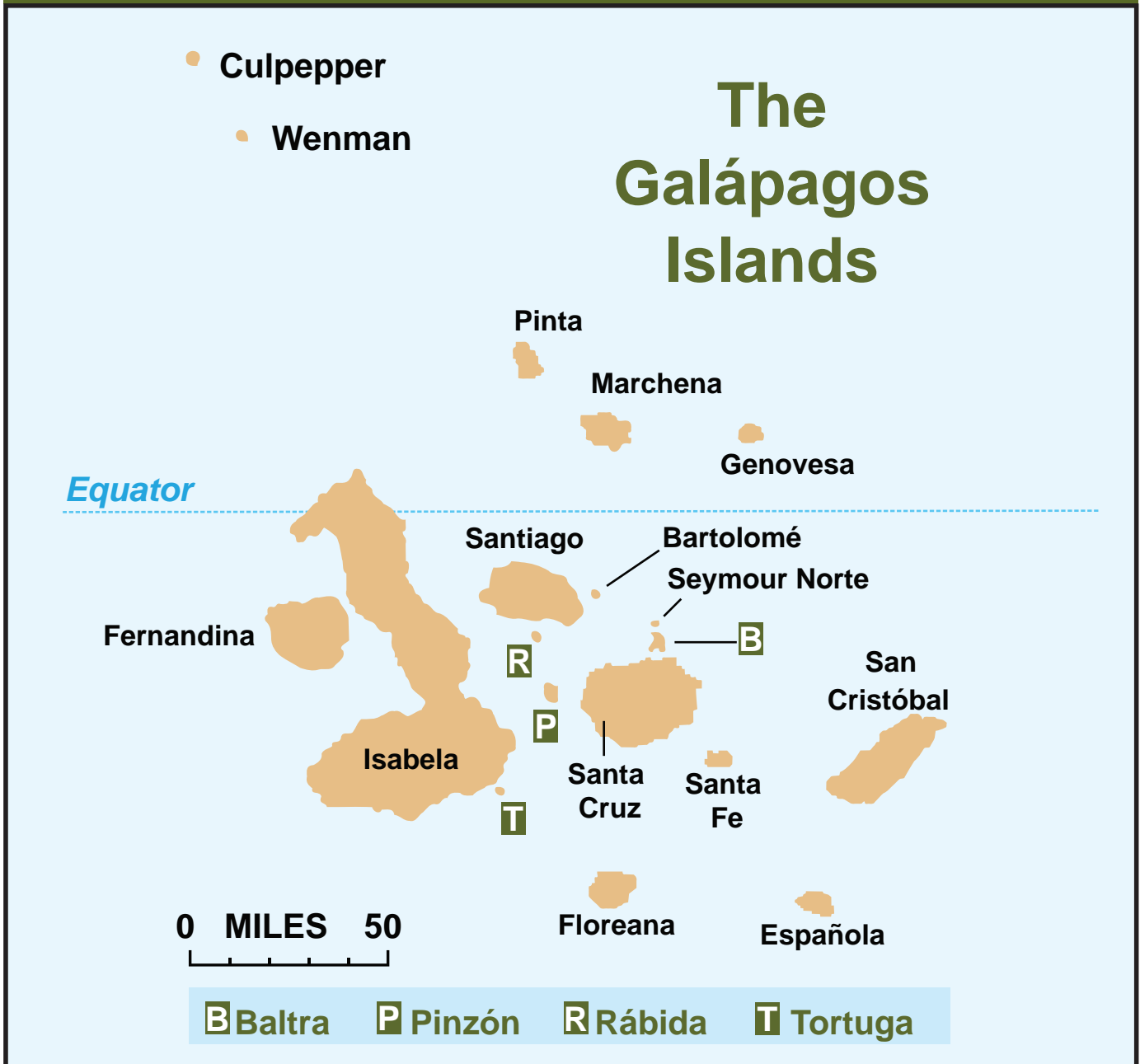
Island Redberry versus Redberry (Mainland)

Redberry (Mainland)



Island Redberry

Map of Galápagos Islands

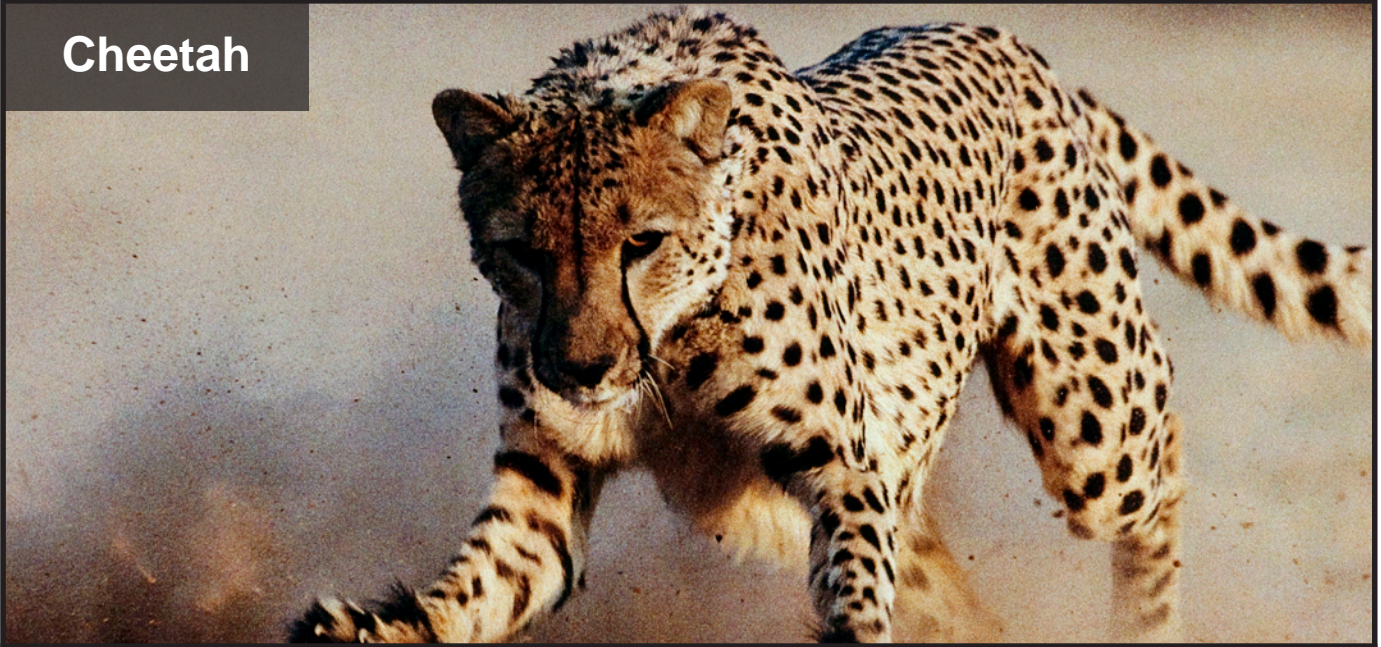


Giant Tortoise Subspecies Morphology



Cheetah and Lion

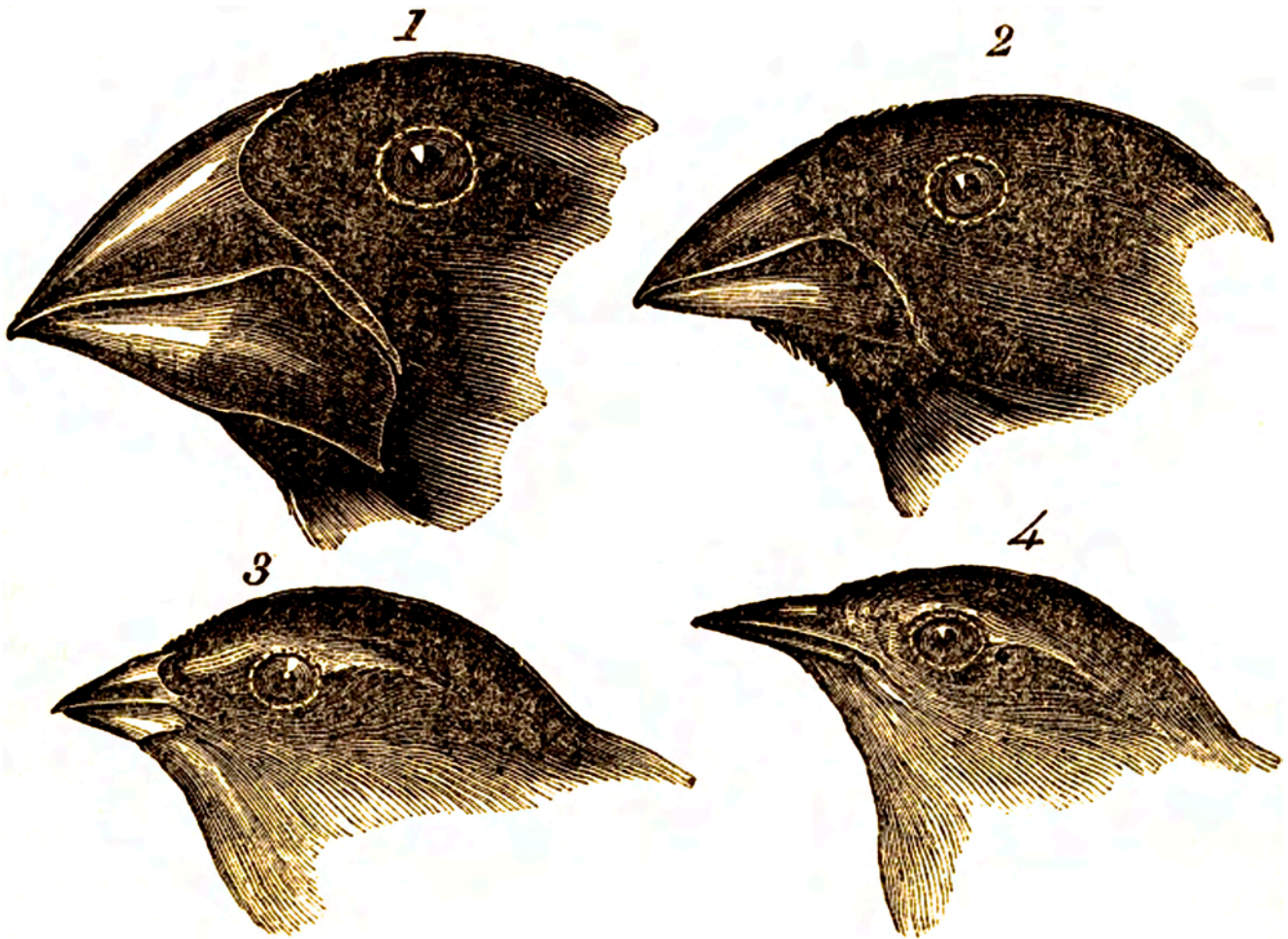
Cheetah



Lion



Galápagos Finch Species



1. *Geospiza magnirostris*.
3. *Geospiza parvula*.

2. *Geospiza fortis*.
4. *Certhidea olivacea*.

Habitat Change and Species Isolation

Lesson 3 Activity Master

Name: _____

1. Make a list of five human activities that affect the populations of tigers. Explain how each activity affects these populations. (2 points each)

2. Describe the correlation between the current range of tiger populations and land use in Southeast Asia. (2 points)

3. How might changes in land use practices contribute to the dramatic decrease in the tiger's range, from historical times to the present? (3 points)

4. Summarize how human activities have increased the isolation of populations of species. (5 points)

Tiger Species Information



Species Information

- Eight documented subspecies of tiger existed historically.
- As of 2007, only five subspecies remain, and all are listed as endangered.
- Length: average 3 meters.
- Weight: 300 kilograms.
- Age: 15 years in the wild.
- Reproduction: Gestation of 16 weeks, three to four cubs in a litter.

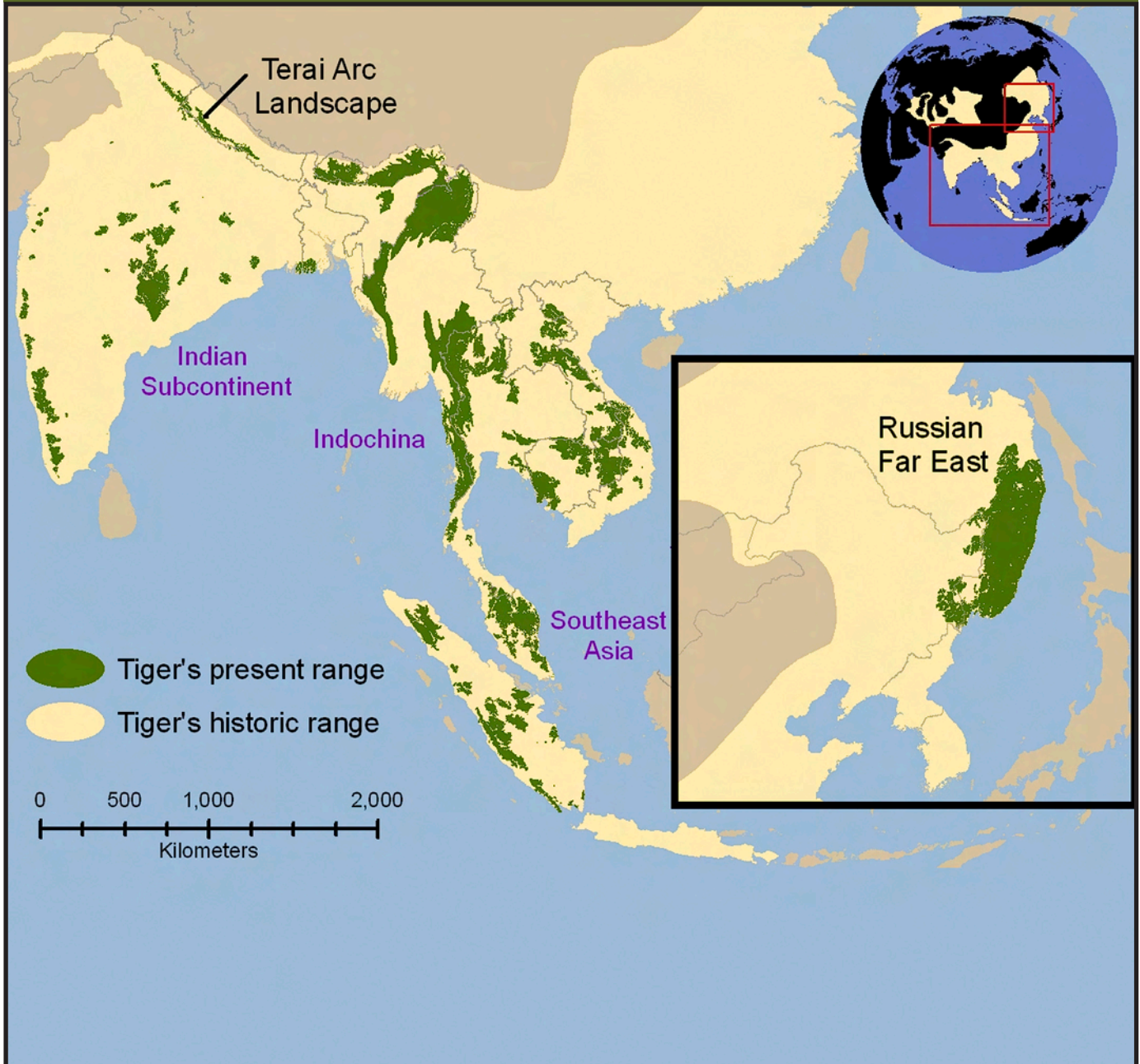
Habitat

- Dense vegetation found in forested areas and a regular water source.
- Currently, they occupy only 7% of their historical range.

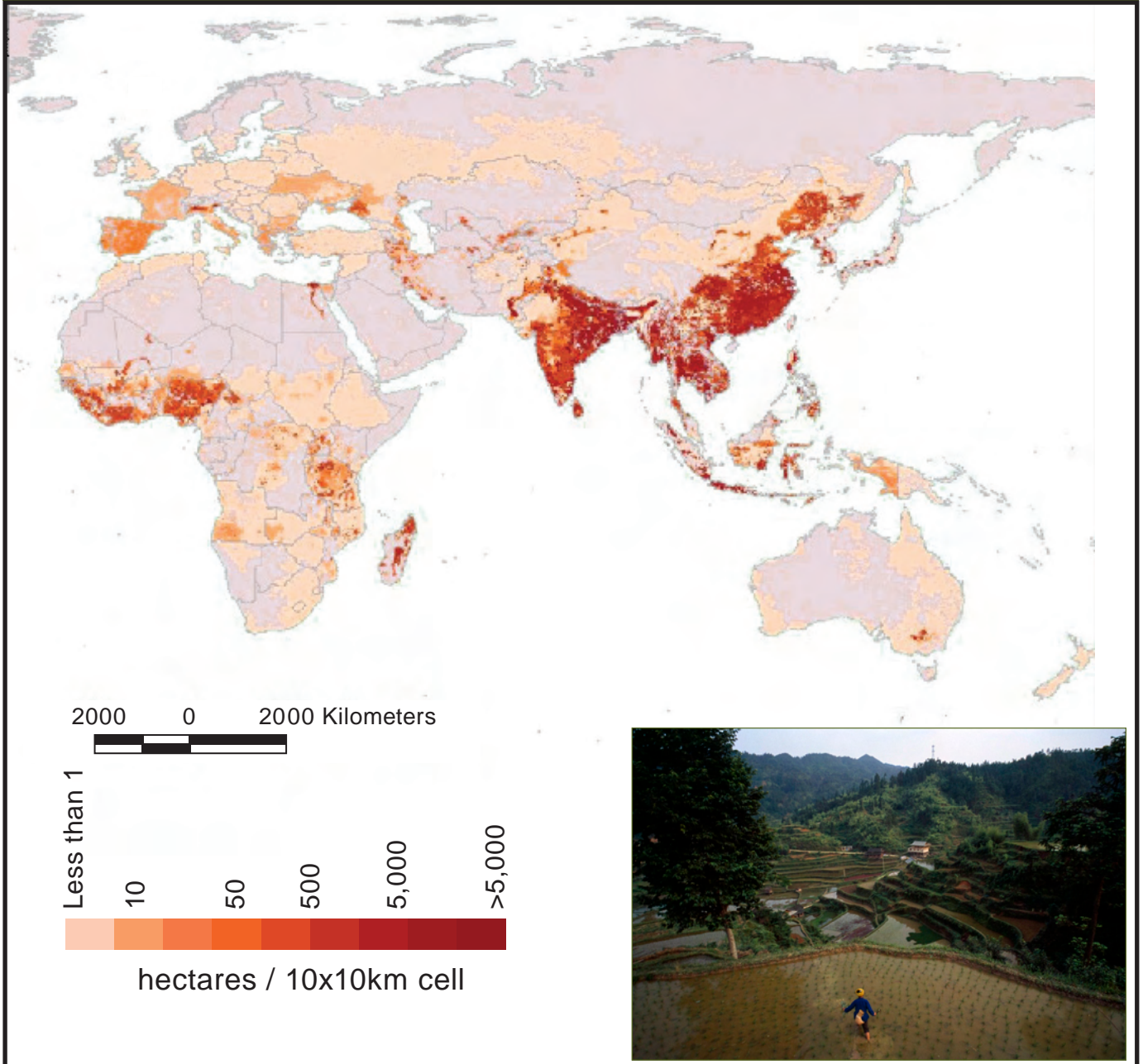
Status

- Endangered status is the result of many types of human activities, including hunting for trophies, use of their body parts for medicinal purposes, deforestation of habitat, and loss of food sources.
- Expanding human populations in the region have altered land use practices, increasing deforestation:
 - Forested regions have been converted to agricultural uses.
 - Commercially-valuable tropical woods have been heavily harvested.
 - Expansion of urban areas including new roads and industrial expansion has fragmented forest habitats.
 - Hydroelectric dams have altered water sources, decreasing suitable habitat.

Tiger Distribution



Land Use Map A

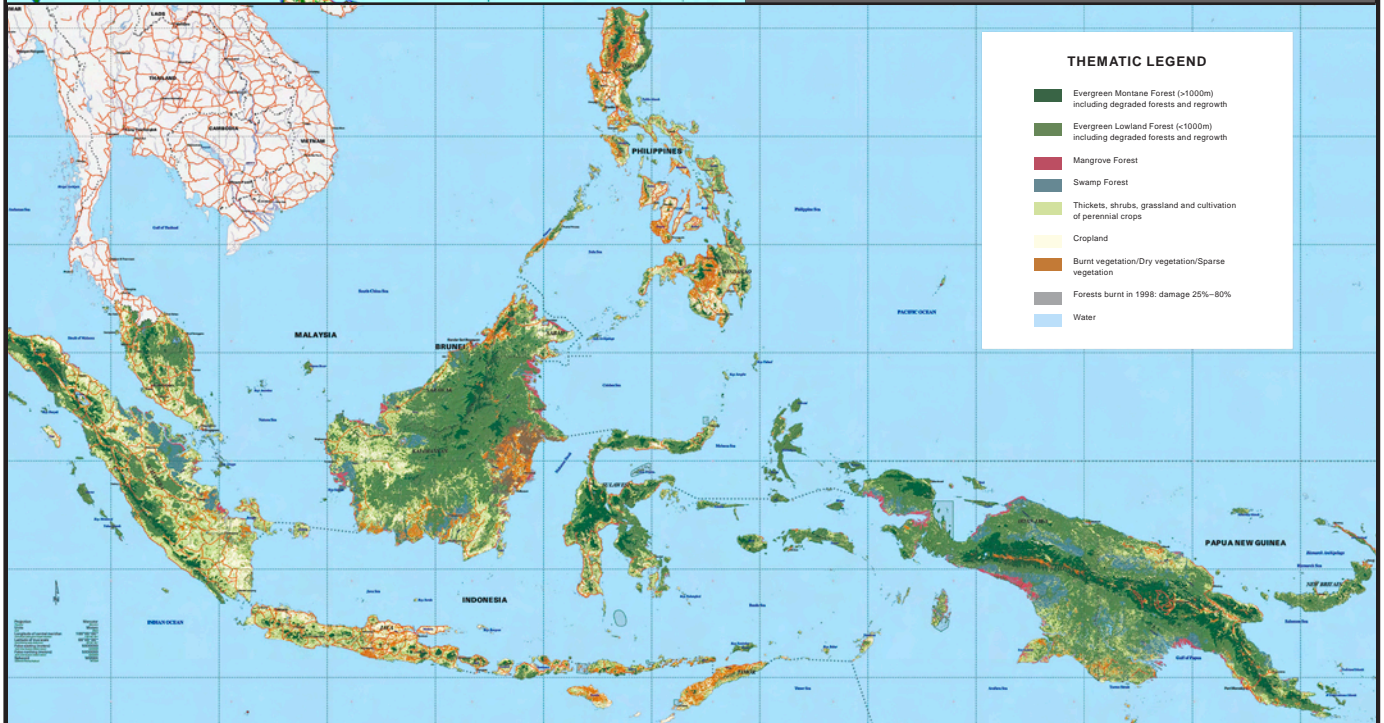


Land Use Map B



Prior to human development, the majority of this region was forested. The remaining forested region is indicated in varying shades of green.

Beige and pink areas represent altered natural habitat for agriculture or urbanization.



Land Use Map C



Reference: Forest cover map of continental southeast Asia, H.J. Stibig and R. Beuchle

Non-native Species

Lesson 4 Activity Master | page 1 of 2

Name: _____

Non-native Species (Native Source)	Organism Characteristics	Invaded Region	How Introduction Occurred Date of Arrival	Former Barrier (1 point each)	Predictions: Influence on Native Species (Plants and Animals) (1 point each)	Consequences: Effects on Geographic isolation of native populations (1 point each)
Blackberry (South American Continent)	<ul style="list-style-type: none"> Thorny bush that grows in thick hedges up to 4 meters high Produces thousands of seeds per bush that are viable for many years in the soil Can reproduce within 3 months after germination 	Galápagos, Ecuador	Unknown 1900s			
Feral Goats (South American Continent)	<ul style="list-style-type: none"> Strong grazers of vegetation, generalist feeders Digs in the soil Reproduces quickly 	Galápagos, Ecuador	Intentional-Ranching 1800s			

Non-native Species

Lesson 4 Activity Master | page 2 of 2

Name: _____

Non-native Species (Native Source)	Organism Characteristics	Invasion Region	How Introduction Occurred Date of Arrival	Former Barrier (1 point each)	Predictions: Influence on Native Species (Plants and Animals) (1 point each)	Consequences: Effects on Geographic Isolation of native populations (1 point each)
Black rats (Channel Islands, California, USA)	<ul style="list-style-type: none"> Adapts quickly to harsh 	Channel Islands, CA, USA	Accidental- Exploration ships (invaded every island visited by ships) Unknown			

Changes in Populations

Lesson 4 Activity Master

Group	Increases in Population Numbers	Decreases in Population Numbers
General Animals (applies to all animal groups)	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	<ul style="list-style-type: none"> ■ disease ■ pollution ■ decrease in food resources ■ over-exploitation (hunting/fishing) ■ increase in predators ■ loss of suitable habitat
Mammals	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	Same as general plus: <ul style="list-style-type: none"> ■ disruption of migratory routes ■ illegal wildlife trafficking
Birds	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	Same as general plus: <ul style="list-style-type: none"> ■ loss of nesting sites is part of loss of suitable habitat ■ predation of eggs and nestlings ■ collection for pet trade
Amphibians	Same as general plus: <ul style="list-style-type: none"> ■ pollution regulation (very sensitive to pollution due to strong association with water) 	Same as general plus: <ul style="list-style-type: none"> ■ collection for pet trade
Reptiles	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	Same as general plus: <ul style="list-style-type: none"> ■ loss of nesting sites ■ predation of eggs and nestlings ■ collection for pet trade
Fish	Same as general plus: <ul style="list-style-type: none"> ■ protected status currently mainly applies mainly to sharks) 	Same as general plus: <ul style="list-style-type: none"> ■ loss of spawning sites ■ habitat degradation due to algal overgrowth ■ predation of eggs and larvae ■ collection for pet trade
Plants	<ul style="list-style-type: none"> ■ irrigation ■ pesticides ■ restoration ■ erosion prevention 	<ul style="list-style-type: none"> ■ diversion of water sources ■ increased grazing ■ over-growth by other plants ■ loss of habitat ■ competition for sunlight, water, or nutrients with other plants

Blackberry

The blackberry is at the top of list for introduced plants that threaten native plant species in the Galápagos Islands. This species often overgrows native species and out-competes them for space, light, and water. Its seeds are easily dispersed by birds that consume their fruit, allowing the plants to colonize vast areas rapidly. Blackberries also form thick, thorny hedges that cannot be crossed by some animals.

Feral Goats

Goats are strong grazers, so they compete with native species, especially in isolated parts of the Galápagos Islands where vegetation is sparse. They have completely altered natural regions, changing forested areas into grasslands. The removal of vegetation has increased erosion, further altering the landscape. Additionally, giant tortoises cannot survive where the goats have removed the vegetation because the tortoises no longer have food.

Black Rats

Black rats are a known stowaway on ships since humans began exploring the world. They have been introduced to over 80% of the world's islands. Their introduction is estimated to be responsible for 40-60% of all bird and reptile extinctions in the world. Because the main part of their diet is eggs, they can dramatically affect populations of ground-nesting birds. They also eat vegetation, resulting in reduced populations of native plant species. In addition, black rats carry many diseases that can ravage native animal populations. They affect native species by competing with them for similar food resources and predating on them directly.

Red Fire Ants

Red Fire Ants, when imported, have a dramatic affect on young birds, small mammals, amphibians, and reptiles through competition and consumption as prey. They are very aggressive and territorial, especially around their nests. As part of their defense, they will attack and sting organisms as large as a juvenile deer. Red Fire Ants have also reduced populations of native insects that protect plants from insects that eat them. In addition, fire ants consume vegetation.

Summary Questions

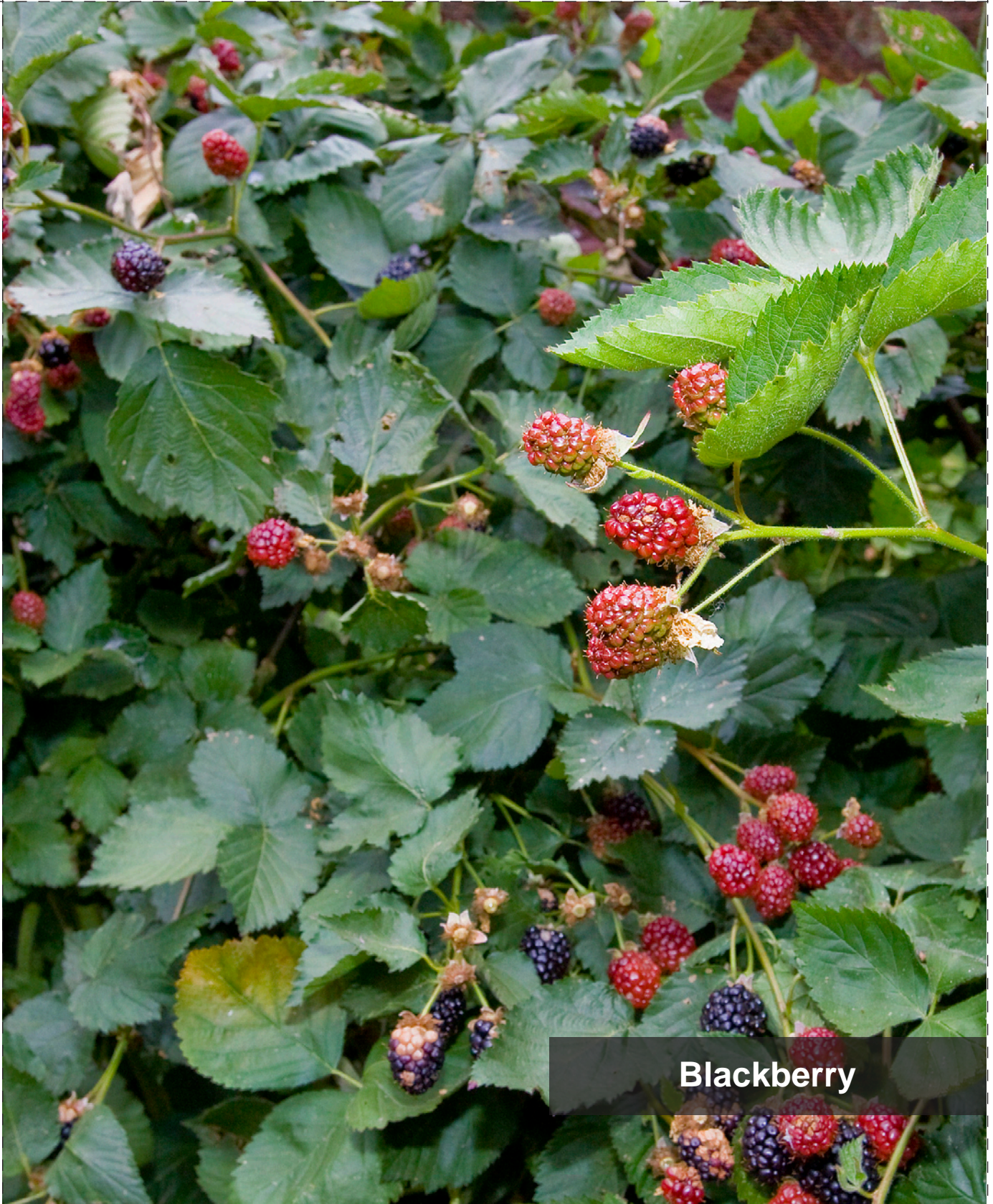
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Name: _____

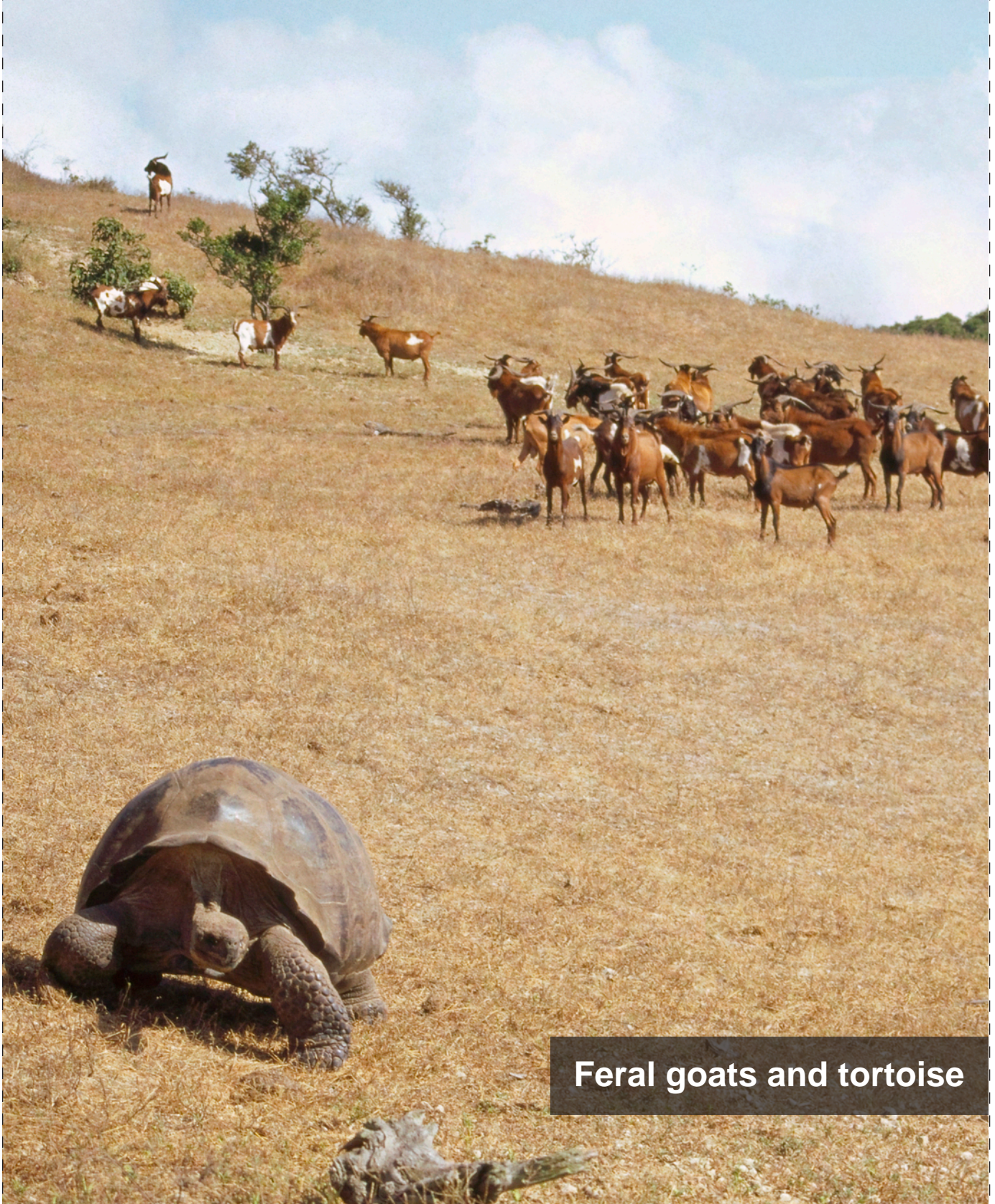
1. Identify and describe three specific ways that non-native species directly influence changes in the populations of native species. (5 points each)

2. Explain how these changes influence the native species population, including how decreasing population size influences genetic diversity. (5 points)

3. How can these changes contribute to an increase in the geographic and reproductive isolation of native species? (5 points)



Blackberry



Feral goats and tortoise



Black rats



Red Fire Ants

Non-native Species

Non-native Species (Native Source)	Organism Characteristics	Invaded Region	How Introduction Occurred Date of Arrival	Former Barrier (1 point each)	Predictions: Influence on Native Species (Plants and Animals) (1 point each)	Consequences: Effects of Geographic Isolation on native populations (1 point each)
Blackberry (South America)	<ul style="list-style-type: none"> ■ Thorny bush that grows in thick hedges up to 4 meters high ■ Produces thousands of seeds per bush that are viable for many years in the soil ■ Can reproduce within 3 months after germination 	Galápagos, Ecuador	Unknown 1900's			
Feral Goats (South America)	<ul style="list-style-type: none"> ■ Strong grazers of vegetation, generalist feeders ■ Digs in the soil ■ Reproduces quickly 	Galápagos, Ecuador	Intentional-Ranching 1800s			

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Changes in Populations

Group	Increases in Population Numbers	Decreases in Population Numbers
General Animals (applies to all animal groups)	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	<ul style="list-style-type: none"> ■ disease ■ pollution ■ decrease in food resources ■ over-exploitation (hunting/fishing) ■ increase in predators ■ loss of suitable habitat
Mammals	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	<i>Same as general plus:</i> <ul style="list-style-type: none"> ■ disruption of migratory routes ■ illegal wildlife trafficking
Birds	<ul style="list-style-type: none"> ■ protected areas ■ breeding programs ■ habitat regeneration ■ protection status 	<i>Same as general plus:</i> <ul style="list-style-type: none"> ■ loss of nesting sites is part of loss of suitable habitat ■ eggs being preyed upon ■ collection for pet trade
Amphibians	<i>Same as general plus:</i> <ul style="list-style-type: none"> ■ pollution regulation (very sensitive to pollution due to strong association with water) 	<i>Same as general plus:</i> <ul style="list-style-type: none"> ■ collection for pet trade
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Plants	<ul style="list-style-type: none"> ■ irrigation ■ pesticides ■ restoration ■ erosion prevention 	<ul style="list-style-type: none"> ■ diversion of water sources ■ increased grazing ■ over-growth by other plants ■ loss of habitat ■ competition for sunlight, water or nutrients with other plants

Consequences of Introduction

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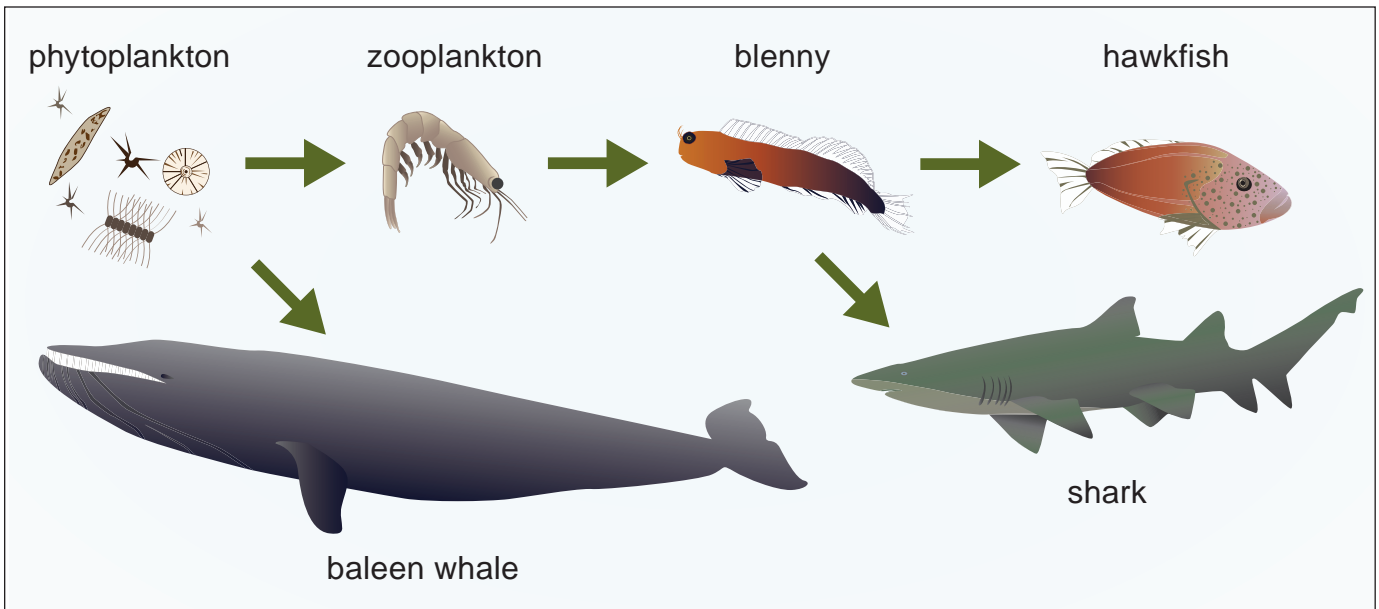
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Name: _____

Case Study

Galápagos Islands, Ecuador



Overview of El Niño Phenomenon

El Niño is a cyclic phenomenon that has a great influence on life in the Pacific Ocean, and worldwide effects on climate. It occurs about every 2–10 years. The last major El Niño was in 1997–1998; however, several “minor” El Niño have occurred since then. The main indicator of El Niño is warming of ocean surface waters in June and July in the equatorial Pacific. This warm water moves eastward along the equator toward the Galápagos Islands. Upwellings of nutrient-rich water that usually occur along the western side of the islands cease, resulting in decreased amounts of nutrients for phytoplankton—the base of the marine food chain.

Phytoplankton use chlorophyll, just like land plants, to harvest the energy of the Sun and grow. The concentration of chlorophyll

in seawater samples is used to determine the concentration of phytoplankton in the ocean. Less chlorophyll means lower concentrations of phytoplankton. This means there will be lower levels of zooplankton (microscopic animals) and fewer of the animals that feed on zooplankton. The change in nutrients and water temperature also affects the type of seaweeds (algae) found in the Galápagos Islands. Normally, red and green algae, the preferred food of marine iguanas, are abundant. During El Niño years, this algae dies off and is replaced by a species of brown algae. The brown algae species is less nutritious, or even toxic, to the marine iguana. Changes also occur on the land; the Galápagos Islands, which are usually arid, receive higher amounts of rainfall, which leads to increases in vegetation.

Island Species and Environmental Change: Part 1

Lesson 5 Activity Master | page 2 of 2

Name: _____

Describe the trends that occur in the Galápagos for an El Niño year versus a normal year for each of the following parameters. (2 points each)

1. Sea Surface Temperature: How do sea surface temperatures differ between a normal and El Niño year on the Galápagos Islands?

2. Phytoplankton concentration: “How does phytoplankton abundance differ between normal years and El Niño years on the Galápagos Islands?”

3. Rainfall: How does the pattern of rainfall differ between a normal and El Niño year on the Galápagos Islands?

Island Species and Environmental Change: Part 2

Lesson 5 Activity Master

Name: _____

Animal Species	Habitat	Food Source	Behavior	Potential Effects of El Niño on Island Dwelling Organisms
Marine iguana	Rocky coastal areas, shallow reefs	Red or green algae	Lays eggs in sandy, terrestrial burrows	
Flightless cormorant	Near-shore coastal areas, rocky coastal areas on Fernandina and Western Isabela	Small fish and octopus	Builds seaweed nests in near-shore coastal areas above the high tide line	
Galápagos penguin	Rocky coastal areas and open ocean	Small fish and crustaceans	Nests in rocky crevices	

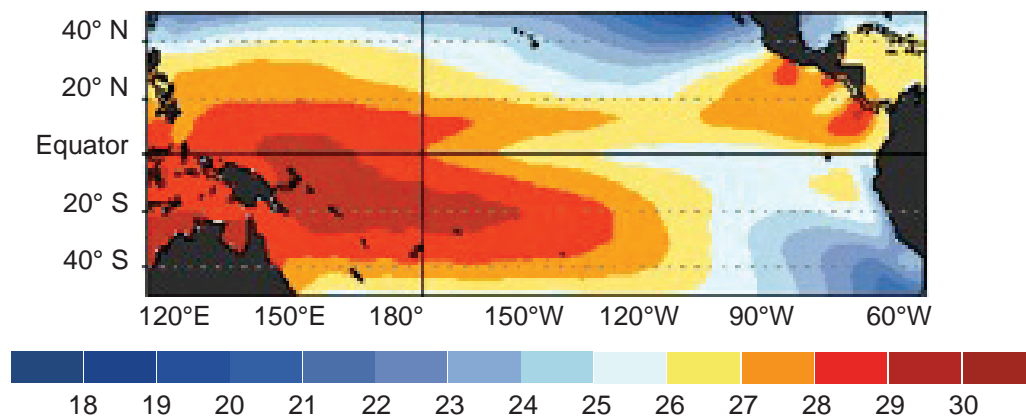
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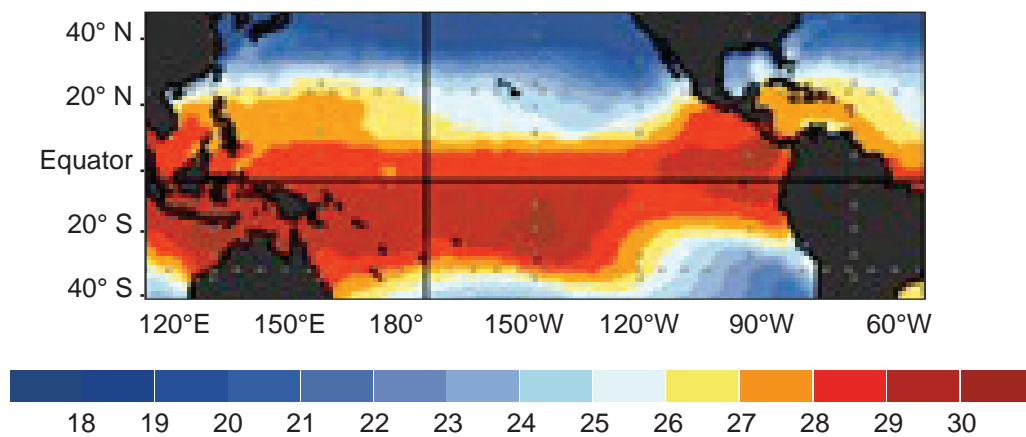
Lesson 5 Activity Master | page 2 of 2

Sea Surface Temperatures

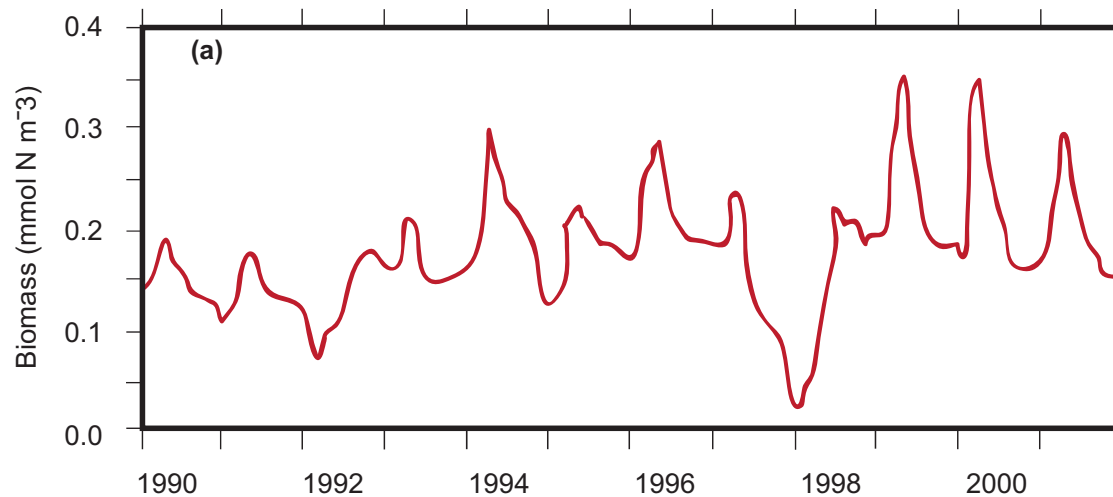
**Average Ocean Temperatures (° C)
January–March**



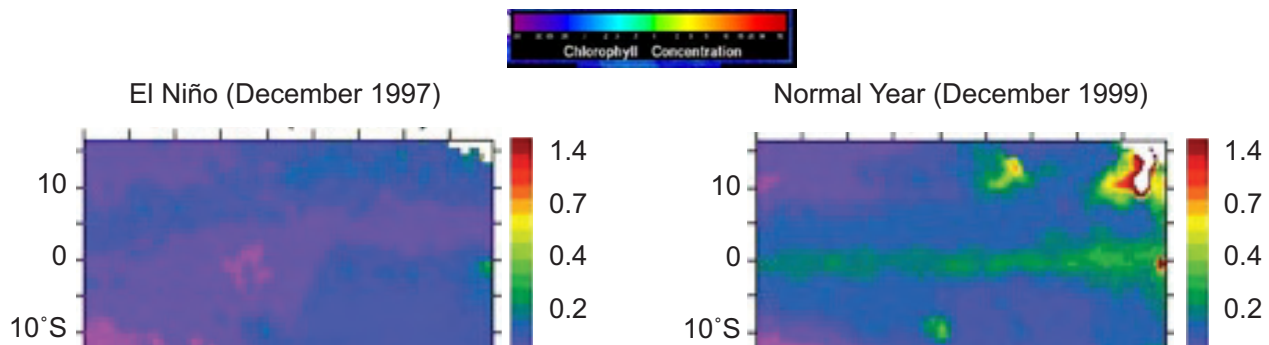
**El Niño
January–March 1998**



Phytoplankton Concentration

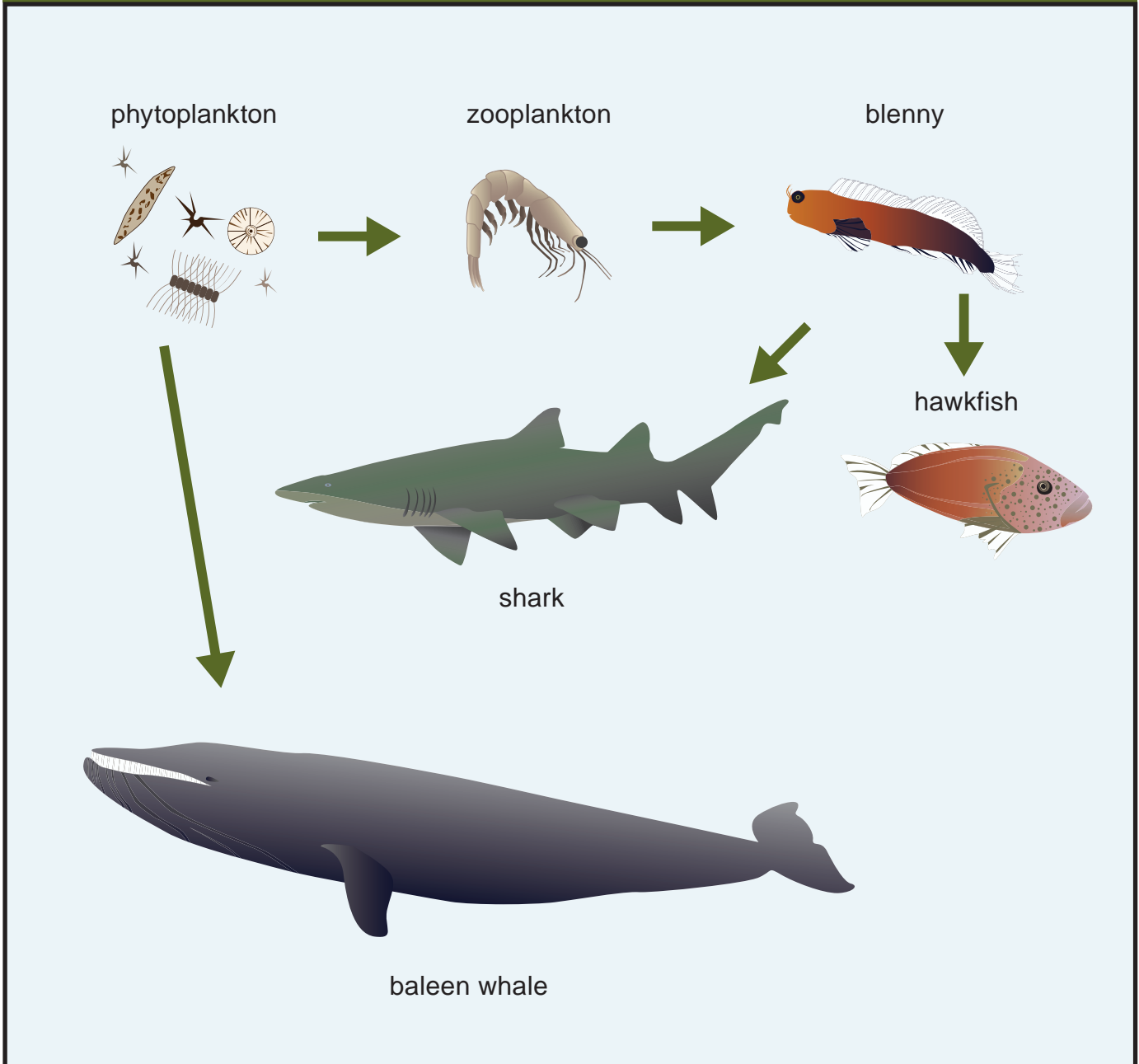


Surface chlorophyll (mg m^{-3})
from SeaWiFS imagery in the equatorial Pacific Ocean

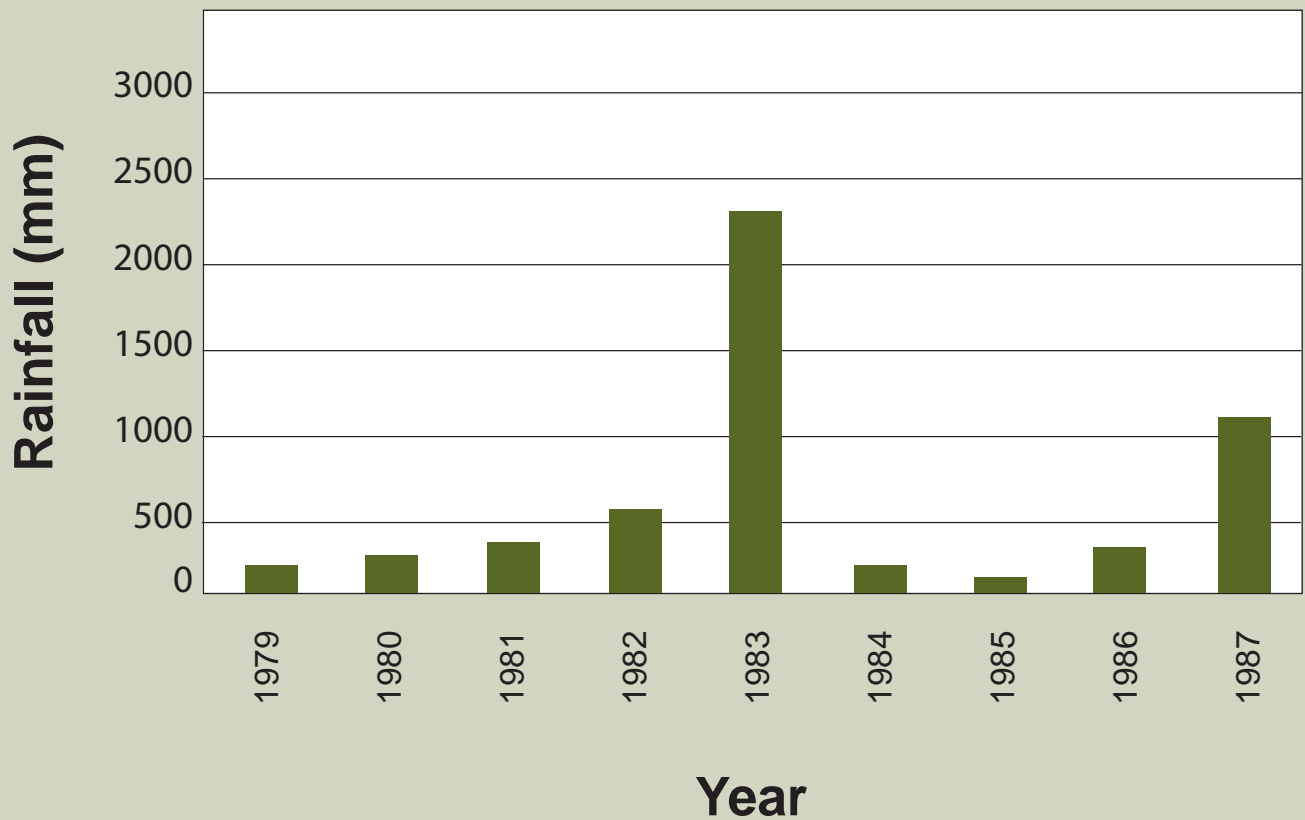


Chlorophyll concentration in the region around the Galapagos Islands as shown through satellite imagery. The image on the right reflects phytoplankton abundance. Red and orange coloration indicated higher concentrations while blue and purple indicated low concentrations.

Marine Food Web



Rainfall Data



As recorded at the Charles Darwin Research Station in Puerto Ayora, Santa Cruz, Galápagos, Ecuador. Note the increased rainfall during 1983 and 1987, two of the recognized El Niño years.

Land Iguana



Marine Iguana



Flightless Cormorant



Fernandina, Galápagos, Ecuador

Galápagos Penguin



**Galápagos Penguin and its rocky habitat
Bartolomé, Galápagos, Ecuador**

Population Changes and El Niño

Animal Species	Species	Changes in the Population	Influential Parameter
	Marine iguana	<ul style="list-style-type: none"> ■ 30% decrease in body size ■ 50% decline in numbers 	<ul style="list-style-type: none"> ■ Decline in available food resources (red/green algae)
	Flightless cormorant	<ul style="list-style-type: none"> ■ 45% decrease in numbers 	<ul style="list-style-type: none"> ■ Decline in available food resources (fish)
	Galapagos penguin	<ul style="list-style-type: none"> ■ 78% decrease in numbers (1982–1983) — downward population trend 	<ul style="list-style-type: none"> ■ Decline in available food resources (fish)

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